

Appendix D Construction

D-1. General

Construction is a critical phase in achieving a safe dam because operational problems often go back to mistakes made in design and construction (James 1990). Projects must be continuously evaluated and "re-engineered," as required, during construction, to ensure that the final design is compatible with conditions encountered during construction (Federal Emergency Management Agency 1979). Construction considerations of earth and rock fill dams are discussed in EM 1110-2-2300 and EM 1110-2-1911.

D-2. Construction/Design Interface

Dam safety is an integral part of the planning, design, construction, and operation of a dam. Construction/design interface is essential. This is accomplished through the report on engineering considerations and instructions to field personnel, preconstruction orientation for the construction engineers by the designers, and required visits to the site by the designers.

D-3. Problems to Watch for During Construction

Specific problems with safety implications to watch for during construction include (James 1990):

a. Contacts between fill and rock or concrete.

(1) Problems due to dissimilar compressibility leading to differential settlement and voids or cracks within the embankment.

(2) Critical areas at rock abutments (particularly for steep slopes or slope breaks), spillway contacts, adjacent to conduits, and at contacts with existing fill which have had time to undergo settlement.

(3) Problems of placement and compaction complicated because of restricted access.

(4) Initial fill placement on rock foundation.

b. Failure to detect and remove localized areas of soft foundation material.

(1) Potential differential settlement and cracking.

(2) Important factor in stability of dam and foundation.

c. Preparation and treatment of cutoffs in foundations and abutments - one of the most important factors in embankment dam construction.

(1) Failure to achieve an adequate cutoff to sound rock or an impervious strata.

(2) Failure to achieve adequate reduction in seepage volume or pressure with grout curtain or to seal off large channels or voids.

(3) Failure to achieve adequate surface treatment of joints, potholes, treatment of overhangs, loose rock on abutments, or inadequate bond between embankment and foundation.

d. Construction problems during installation of drains and filters.

(1) Piping can result from failure to achieve filter criteria due to segregation of material which may occur in transition to rockfill or in exit details.

(2) Inadequate drainage capacity because of improper gradation, dirty (excessive amount of fines) materials, material breakdown during placement, or contamination of the filter with impervious material from the adjacent core due to traffic or due to surface erosion caused by rainfall.

e. Failure to detect critical zones such as voids or strata, or lenses, of pervious materials in foundations without cutoffs.

(1) Inadequate or no pressure relief.

- (2) Lack of control over exits.

D-4. Obtaining Quality Construction

a. Definitions (ER 1180-1-6).

(1) Quality is conformance to properly developed requirements. In the case of construction contracts, these requirements are established by the contract specifications and drawings.

(2) Quality management is all control and assurance activities instituted to achieve the product quality established by the contract requirements.

(3) Contractor quality control (CQC) is the construction contractor's system to manage, control and document his own, his supplier's and his subcontractor's activities to comply with contract requirements.¹

(4) Quality Assurance (QA) is the procedure by which the Government fulfills its responsibility to be certain the CQC is functioning and the specified end product is realized.

b. Policy. Obtaining quality construction is a combined responsibility of the construction contractor and the Government. The contract documents establish the level of quality required in the project to be constructed. In contracts of \$1,000,000 or greater, detailed CQC will be applied and a special clause will be included in the contract. Guidance in preparing this clause is given in Appendix A of ER 1180-1-6. QA is required on all construction contracts. The extent of assurance is commensurated with the value and complexity of the contracts involved. QA testing is required (ER 1180-1-6).

c. Contractor responsibility. Contractors shall be responsible for all activities necessary to manage,

control, and document work so as to ensure compliance with the contract plans and specifications (P&S). Contractor's responsibility includes ensuring that adequate quality control services are provided for work accomplished by his organization, suppliers, subcontractors, technical laboratories and consultants. For contracts of \$1,000,000 or greater, contractors will be required to prepare a quality control plan (see Appendix A of ER 1180-1-6) (ER 1180-1-6).

d. Government responsibility. QA is the process by which the Government assures end product quality. This process starts well before construction and includes reviews of the P&S for biddability and constructibility, plan-in-hand site reviews, coordination with using agencies or local interests, establishment of performance periods and quality control requirements, field office planning, preparation of QA plans, reviews of quality control plans, enforcement of contract clauses and acceptance of completed construction (ER 1180-1-6).

e. Quality assurance for procedural specifications. Some QA testing in the case of earthwork embankment and concrete dam structures must be conducted continuously. A comprehensive QA testing program by the Government is necessary when specifications limit the contractor to prescriptive procedures leaving the responsibility for end product quality to the Government (ER 1180-1-6).

D-5. Construction Records and Reports

a. General. Engineering data relating to project structures will be collected and permanently retained at the project site as specified in Appendix A of ER 1110-2-100 and EM 1110-2-2300. This information has many uses such as determining the validity of claims made by construction contractors, designing future alterations and additions to the structure, familiarizing new personnel with the project and providing guidance for designing comparable future projects. These documents will include as many detailed photographs as necessary. This information is crucial to dam safety because it provides the basis for analysis and remedial action in the event of future distress.

¹ Additional information is given in EP 715-1-2, "A Guide to Effective Contractor Quality Control (CQC)" and International Commission on Large Dams Bulletin 56 "Quality Control for Fill Dams" (International Commission on Large Dams 1986).

b. *Field control data.* As required by EM 1110-2-2300, records including field control data on methods of compaction, in-place unit weight and moisture content, piezometers, surface monuments and slope indicators are kept for use in construction, operation and maintenance of the project. Instructions regarding specific forms to use for field data control are given in ER 1110-2-1925.

c. *As-constructed drawings.* As construction of a project progresses, plans will be prepared showing the work as actually constructed. Changes may be indicated in ink on prints of the construction drawings or the tracings may be revised and new prints made to show the work as constructed, as specified in ER 1110-2-1200.

d. *Embankment criteria and foundation report.* Earth and earth-rockfill dams require an embankment criteria and foundation report to provide a summary of significant design assumptions and computations, specification requirements, construction procedures, field control and record control test data and embankment performance as monitored by instrumentation during construction and during initial reservoir filling. This report is usually written by persons with first hand knowledge of the project design and construction. The written text is brief with the main presentation consisting of a set of identified construction photographs, data summary tables, and as constructed drawings. This report is important to dam safety because it provides in one volume the significant information needed by engineers to familiarize themselves with the project and to reevaluate the embankment in the event unsatisfactory performance occurs (see ER 1110-2-1901).

e. *Construction foundation report.* In addition to an embankment criteria and foundation report, all

major and unique dams require a construction foundation report to be completed within 6 months after completion of the project or part of the project for which the report is written (see Appendix A of ER 1110-1-1801 for a suggested outline for foundation reports). This report documents observations of subsurface conditions encountered in all excavations and provides the most complete record of subsurface conditions and treatment of the foundation. The construction foundation report is important to dam safety because it saves valuable time by eliminating the need to search through voluminous construction records of the dam to find needed information to use in planning remedial action should failure or partial failure of a structure occur as a result of foundation deficiencies.

f. *Photographs and video tape taken during construction.* Embankment criteria and foundation and construction foundation reports should be supplemented by photographs that clearly depict conditions existing during embankment and foundation construction. Routine photographs should be taken at regular intervals, and additional pictures should be taken of items of specific interest, such as the preparation of foundations and dam abutments. For these items, color photographs should be taken. The captions of all photographs should contain the name of the project, the date on which the photograph was taken, the identity of the feature being photographed and the location of the camera. In reports containing a number of photographs, an alternative would be an index map with a circle indicating the location of the camera with an arrow pointing in the direction the camera was pointing, with each location keyed to the numbers on the accompanying photographs (EM 1110-2-1911). Consideration should be given to using video tape where possible to document construction of the dam.